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Effect of Hydrocolloids on Nutritional and Rheological Properties of Tomato Ketchup

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Hydrocolloids are polysaccharides that are frequently utilized as stabilizing, gelling, suspending, and thickening agents. The study aimed to investigate the impact of various hydrocolloids on the nutritional, rheological, and organoleptic properties of tomato ketchup. After extraction of tomato pulp, ketchup (a value-added tomato product) was prepared using starch, guar gum, carboxymethylcellulose (CMC), and pectin as hydrocolloids at a level of 2%, 2%, 2%, and 2% respectively. The proximate composition results of different tomato ketchup treatments indicated that guar gum ketchup showed significant nutritional quality with the highest protein content of 3.66±0.006. The results regarding physiochemical analysis of different tomato ketchup treatments revealed that during storage, the pH of tomato ketchup decreased, the acidic flavor increased, TSS decreased and the overall textural profile decreased with the increase in storage time. Moreover, innovative chocolate showed higher antioxidant activity as compared to control in different storage intervals. In addition, ketchup prepared with hydrocolloids showed higher sensory scores as compared to the control sample. The findings suggest that hydrocolloids are used in ketchup to improve its nutritional value and rheological, and organoleptic properties.
Keywords: Tomato ketchup, hydrocolloids, physiochemical analysis, shelf stability.

INTRODUCTION

Hydrocolloids are high molecular weight polysaccharides that solubilize in water made up of simple sugar building blocks 6-8 and are frequently utilized as stabilizing, gelling, suspending, and thickening agents. These all contain hydrophilic compounds that react with water to create a viscous solution. Food products often incorporate various hydrocolloids, including starch, carboxymethylcellulose, pectin, gelatin, and gum (Baeghbali *et al.,* 2021). These improve viscosity, control crystallization, prevent syneresis, enhance texture, encapsulate flavors, and extend the physical stability of food products. In emulsions, even in small amounts, gums and stabilizers with non-Newtonian rheology give the emulsions a non-Newtonian behavior. Long-term stability is important for sauces to be accepted by consumers and hydrocolloids are commonly used in the food industry for this purpose. In the case of ketchup, which is typically stored at room temperature in supermarkets, its rheological properties may change with different temperatures. This can lead to undesired outcomes such as loss of consistency and separation of serum. Hydrocolloids can be added to ketchup to increase its consistency and reduce serum loss (Manzoor *et al.,* 2020). Tomato (*Solanum lycopersicum* L.), is an herbaceous plant belonging to the Solanaceae family, expected to yield around 180.8 million tons in 2019 (Constantino *et al.,* 2022). It originates from Peru, Ecuador, and some parts of central Mexico. It is widely consumed throughout the world in a variety of processed forms, including canned tomato, sauce, juice, ketchup, stews, and soup (Sugino *et al.,* 2022). They provide significant dietary contributions of fiber, vitamin C, potassium, lycopene, and other carotenoids, all in a low-energy-dense food (Anlar and Bacanli, 2020). Tomatoes are a significant vegetable crop, known for their nutritional value. They are rich in phenolics and organic acids, which have beneficial effects on human health. Lycopene, a powerful antioxidant, is found in abundance in tomatoes. Apart from being consumed fresh, tomatoes are commonly processed into products like puree, ketchup, soup, and paste. Offering a new range of traditional

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tomato products could help diversify the market and reduce post-harvest losses (Al-Dairi *et al.*, 2021). Tomato ketchup, a vegetable sauce with at least 12% tomato solids, is made from properly strained tomatoes along with salt, sugar, spices, vinegar, and sometimes garlic and onion. It is the most significant and widely used condiment, with a substantial number of tomatoes processed for its production. Hydrocolloids are commonly used in various food formulations to enhance quality and shelf life. To improve the consistency of ketchup with lower total solids content, hydrocolloids can be added (Baeghbali *et al.*, 2021). Following Germany and Great Britain, Poland is the region in Europe with the third-highest ketchup consumption. Because it enhances the flavor of various foods, ketchup is a widely used product. Additionally, it is a low-calorie product and simple to use. Additionally, ketchup contains beneficial carotenoids, the most plentiful of which is lycopene. The term "ketchup" refers to a range of products prepared from the strained and spiced pulp of various fruits, with tomato-based ketchup being the most widely used. The qualities of good ketchup include flavor, homogeneity, consistency, and eye-catching color (Wohner *et al.*, 2020). Due to its high lycopene and anti-oxidant content, tomato ketchup plays an important health-promoting role (Bednar *et al.*, 2014). The consistency and viscosity of tomato ketchup play a crucial role in consumer acceptance (Ghandi *et al.*, 2008). However, during storage, tomato ketchup may change consistency due to hydrolysis, leading to undesirable serum separation known as syneresis. These changes are generally disliked by consumers (Komeilyfard *et al.*, 2017). To this problem, stabilizers are added to improve the body, texture, appearance, mouth feel and retards the syneresis of ketchup. The use of stabilizers to improve the sensory attributes of ketchup and enhance profitability in ketchup-making has become a common practice (Igwemeka and Eze 2023). Presently commercial ketchup is mainly stabilized with exotic stabilizers such as guar gum, gelatin, pectin, carboxyl methyl cellulose (CMC), and xanthan gum, among others (Chukwuma and Soladoye, 2012).

The current research was designed to check the effect of four different hydrocolloids starch, guar gum, CMC, and pectin) on the nutritional, rheological, organoleptic, and shelf-life characteristics of tomato ketchup.

MATERIALS AND METHODS

***Materials*:** Fresh tomatoes were sourced from the local market in Multan, selected based on size, shape, color, damage, and maturity level. Garlic, ginger, onion, cinnamon, cloves, sugar, red chili powder, salt, mustard powder, vinegar, sodium benzoate, and hydrocolloids were also purchased locally. All chemicals were provided by the Department of Agronomy, MNS University of Agriculture, Multan.

Methods

***Preparation of tomato ketchup*:** Tomato ketchup was prepared using various hydrocolloid formulations (starch, guar gum, CMC, pectin) at a 2% concentration, following the treatment plan outlined in Table 1. I chose these hydrocolloids because they are extensively studied and have established roles in modifying texture, viscosity, and stability. I chose a 2% concentration of each hydrocolloid because, at a 2% concentration, many hydrocolloids like starch, guar gum, CMC, and pectin effectively demonstrate their thickening, gelling, or stabilizing properties without oversaturating the system.

Table 1. Treatment plan for the preparation of tomato ketchup.

Treatments	Hydrocolloids	Storage				
		0	15	30	45	60
T_0 (Control group)	0					
T_1	Starch (2%)					
T_2	Guar Gum (2%)					
T_3	CMC (2%)					
T_4	Pectin (2%)					

***Nutritional and Mineral Composition*:** The nutritional analysis followed AOAC (2010) guidelines, including moisture, ash, crude fat, protein, and fiber content. For mineral analysis, samples were digested using a nitric-perchloric acid mixture, and minerals such as calcium, potassium, magnesium, and sodium were quantified using a flame photometer.

***Physicochemical Properties*:** pH, total acidity, and total soluble solids (TSS) were measured following AOAC (2010). The texture was assessed using a CT3 texture analyzer (Mirzaei *et al.*, 2018), while rheological behavior was evaluated with a parallel plate rheometer (Mirzaei *et al.*, 2018). Sensory evaluation involved a hedonic scale to assess attributes like flavor, appearance, and overall acceptability by 15 trained evaluators (Cai *et al.*, 2020). Each researcher was provided with a plate of ketchup, a 250 mL water bottle, and a sensory evaluation sheet.

***Storage Study*:** Tomato ketchup was stored at 4°C, and sensory evaluations were performed at intervals (0, 15, 30, 45, and 60 days) to monitor changes in quality over time.

***Statistical analysis*:** All analysis was carried out and then statistical analysis was done to evaluate and determine the significant difference among treatments (Montgomery, 2017). Using Statistics 8.1, two-way factorial design ANOVA (analysis of variance) was performed on the derived data (analytical software). The values were reported as mean ± standard deviation. Each sample was divided into three replicates for statistical analysis. At a significance level of 0.05, a significant difference was calculated.

RESULTS

***Nutritional composition of tomato ketchup*:** The results of the nutritional composition of the tomato ketchup sample are given in Table 2. According to Table 2, the highest moisture content value 92.26±1.946 % was found at 15 days storage in T1, and the lowest moisture value 72.69±0.246 % was observed at 0 days' storage in T0. Significant differences ($p<0.05$) were assessed between the treatments when analyzing the moisture content value of the tomato ketchup sample.

Table 2 shows that the maximum protein content was observed at 0 days in T_2 (3.66±0.0064%), whereas a minimum protein content was observed in T_3 (0.71±0.276%) at 60 days of storage. Significant differences ($p<0.05$) were assessed between the treatments when analyzing the protein content value of the tomato ketchup sample.

The fat content remained relatively low throughout the study, with slight variations among treatments. This consistency aligns with consumer expectations for low-fat condiments. Table 2 shows that the maximum fat content was observed at 0 days in T_0 (0.47±0.030 %), whereas a minimum fat content was observed in T_4 (0.07±0.020%) at 60 days of storage. Significant differences ($p<0.05$) were assessed between the treatments when analyzing the fat content value of the tomato ketchup sample.

Fiber levels varied significantly across treatments and over time, indicating that ingredient choices can enhance or diminish fiber content. The interactive effect of treatments and storage times on the fiber content of tomato ketchup indicated that significantly the highest value was observed in the T_4 sample containing pectin at storage times of 0, 15, 30, 45, and 60 days with the mean value of 2.66±0.010 %, 1.87±0.403 %, 1.75±0.387 %, 2.03±0.274 % and 0.99±0.003 % respectively.

According to Table 2, the highest ash content value 1.17±0.218% was found at 0 days storage in T0, and the lowest ash value 0.10±0.021% was observed at 60 days' storage in T1. Significant differences ($p<0.05$) were assessed between the treatments when analyzing the ash content value

Table 2. Nutritional composition of tomato ketchup.

	Treat.	Storage					Mean
		0 day	15th day	30th day	45th day	60th day	
Moisture	T_0	72.69±0.246f	75.40±1.08ef	76.98±1.429def	77.87±1.881c-f	84.65±4.889a-e	77.52±1.909b
	T_1	85.84±0.027a-d	86.13±0.030a-d	87.90±0.358ab	89.53±0.158a	92.26±1.946a	88.33±0.504a
	T_2	83.16±0.134a-e	83.24±0.197a-e	86.31±2.533abc	87.62±3.001ab	90.47±2.418a	86.16±1.657a
	T_3	73.32±0.079f	73.45±0.023f	73.56±0.060f	73.82±0.058f	73.87±0.086f	73.60±0.061c
	T_4	72.73±0.758f	73.73±0.787f	75.81±0.575ef	77.92±0.515c-f	79.52±0.285b-f	75.94±0.584bc
Protein	T_0	3.14±0.075abc	3.14±0.088abc	3.12±0.094abc	2.99±0.010a-d	2.77±0.052b-f	3.03±0.064a
	T_1	2.45±0.055c-g	2.16±0.003d-h	2.09±0.005e-h	2.05±0.017e-h	2.02±0.005e-h	2.15±0.017b
	T_2	3.66±0.006a	3.44±0.052ab	3.13±0.052abc	2.82±0.082a-e	2.45±0.195c-g	3.10±0.077a
	T_3	1.96±0.006f-i	1.73±0.112g-j	1.55±0.196h-k	1.40±0.261h-k	0.71±0.276k	1.47±0.170c
	T_4	1.7±0.005d	1.62±0.165g-j	1.15±0.063ijk	1.02±0.005jk	1.11±0.424jk	1.32±0.032c
Fat	T_0	0.47±0.030a	0.27±0.079a-d	0.27±0.079a-d	0.23±0.079a-d	0.23±0.079a-d	0.29±0.069a
	T_1	0.38±0.008b	0.35±0.005abc	0.34±0.005a-d	0.33±0.003a-d	0.33±0.005a-d	0.34±0.005a
	T_2	0.21±0.005a-d	0.17±0.060bcd	0.13±0.030cd	0.38±0.035abc	0.44±0.003ab	0.26±0.027ab
	T_3	0.34±0.027a-d	0.24±0.085a-d	0.24±0.063a-d	0.24±0.030a-d	0.31±0.052a-d	0.27±0.051ab
	T_4	0.35±0.021abc	0.26±0.033a-d	0.14±0.033cd	0.12±0.005cd	0.07±0.020d	0.19±0.022b
Fiber	T_0	0.99±0.107d-g	0.85±0.045e-h	0.67±0.030e-h	0.48±0.117fgh	0.41±0.060fgh	0.68±0.072c
	T_1	0.57±0.049fgh	0.56±0.059fgh	0.44±0.052fgh	0.43±0.052fgh	0.26±0.037gh	0.45±0.050cd
	T_2	1.43±0.063b-e	1.45±0.059b-e	1.17±0.100c-f	0.95±0.024d-g	0.87±0.042e-h	1.17±0.057b
	T_3	0.66±0.053e-h	0.39±0.026fgh	0.33±0.102gh	0.18±0.058gh	0.12±0.008h	0.34±0.050d
	T_4	2.66±0.010a	1.87±0.403abc	1.75±0.387bcd	2.03±0.274ab	0.99±0.003d-g	1.86±0.285a
Ash	T_0	1.17±0.218a	0.63±0.003b-h	0.52±0.012c-h	0.44±0.015d-h	0.28±0.042e-h	0.61±0.058b
	T_1	0.80±0.048a-de	0.40±0.052d-h	0.23±0.079fgh	0.17±0.030gh	0.10±0.021h	0.34±0.042c
	T_2	1.04±0.015abc	1.03±0.011abc	1.04±0.003abc	0.75±0.239a-f	0.75±0.233a-f	0.92±0.100a
	T_3	0.77±0.028a-de	0.53±0.034c-h	0.30±0.033e-h	0.28±0.059e-h	0.19±0.030gh	0.41±0.037c
	T_4	1.06±0.008ab	1.02±0.003abc	0.88±0.052a-d	0.69±0.060a-g	0.44±0.052d-h	0.82±0.035a
NFE	T_0	22.24±0.202cde	19.45±0.119fgh	18.43±0.008gh	18.05±0.386h	11.92±0.120i	18.02±0.167c
	T_1	9.94±0.125ijk	10.67±0.130i	10.00±0.517ij	7.59±0.052kl	5.25±0.197l	8.69±0.204d
	T_2	10.84±0.204i	10.70±0.014i	8.17±0.005jk	7.58±0.052kl	5.36±0.291l	8.53±0.113d
	T_3	21.94±1.408de	24.64±0.258ab	24.03±0.005a-d	24.43±0.303abc	25.37±0.255a	24.08±0.446a
	T_4	21.38±0.640ef	22.50±0.517bcde	20.47±0.103efg	18.48±0.284gh	18.56±0.298gh	20.28±0.368b

of the tomato ketchup sample. According to Table 2, the highest NFE content value 25.37±0.255% was found at 60 days storage in T3, and the lowest NFE value 5.25±0.197 % was observed at 60 days storage in T1. Significant differences ($p<0.05$) were assessed between the treatments when analyzing the ash content value of the tomato ketchup sample. This could be because CMC can solubilize and stabilize soluble carbohydrates hence increasing the overall availability of sugars and starches in the sample.

The data illustrates how different formulations affect the nutritional profile of tomato ketchup over time. Variations in moisture, protein, fat, fiber, and ash content are critical for understanding product quality and consumer health implications.

***Physico-chemical properties of ketchup*:** The physicochemical characteristics of the ketchup samples are presented in Table 3. pH and acidity are important factors influencing the quality of tomato ketchup.

The solids content is an important factor in the production of tomato ketchup. It is well known that the higher the total solids the better will be the quality of the end product. The TSS of the ketchup sample ranged between 31.7–52.70 °Brix as compared to the commercial ketchup with 38 °Brix. The TSS range was observed from 42.47±0.030 to 42.87±0.052 °Brix for fresh ketchup samples. Higher TSS was observed for ketchup containing pectin 2% (52.53±0.108°) while the lowest TSS was observed for a sample containing guar gum (31.7±0.052) ° just after preparation. After 60 days of storage, higher TSS was observed for ketchup containing pectin 2% (52.70±0.052) °. Similar trends were reported by Gujral *et al.,* (2002).

There was a slight variation in the values of pH and acidity in the formulated ketchup, the pH ranged between 2.88±0.008 to 3.14±0.005 and acidity was in the range of 0.12 to 0.21 % in the fresh tomato ketchup sample. Higher pH was observed for the control sample (3.14±0.005), while the lowest for ketchup-containing starch was 2% (2.88±0.008). Decrement in pH was observed during storage, and after 60 days of storage minimum pH was found for corn starch and pectin @ 2%. The results align with the findings of Gamonpilas *et al.,* (2011) and Sharoba *et al.* (2005). After preparation, the highest acidity was observed for ketchup containing CMC 2% (0.21±0.005) %, while the lowest was for ketchup containing pectin (T_4) (0.12±0.005) %. The acidity value of tomato ketchup decreases over time, and after 60 days of storage minimum pH was found for corn starch (T_1) and pectin (T_4) @ 2%. The results align with the findings of Gamonpilas *et al.,* (2011) and Sharoba *et al.* (2005).

The Acidity/Brix range was observed (0.002±0.001 to 0.1±0.002) for ketchup samples. Higher Acidity/Brix was observed for samples containing starch (T_1) (0.01±0.0002) while lowest Acidity/Brix was observed for samples containing pectin (T_4) (0.002±0.001) just after preparation. The acidity/Brix value of tomato ketchup increases over time. After 60 days of storage, higher TSS was observed for ketchup containing starch 2% (0.003±0.001) °. The Acidity/Brix range of tomato ketchup samples was found to be in the range of the earlier published reports (Gamonpilas *et al.* 2011; Sharoba *et al.,* 2005).

***Mineral Analysis*:** The mineral content in all samples was determined at 0, 15, 30, 45 and 60 days. The influence of both storage and treatment on the mineral content of tomato

Table 3. Physicochemical analysis of tomato ketchup.

	Treatments	Storage					Mean
		0 day	15th day	30th day	45th day	60th day	
TSS(°Brix)	T_0	42.47±0.030d	42.60±0.030cd	42.67±0.030cd	42.80±0.030cd	42.87±0.052c	42.68±0.048c
	T_1	34.73±0.030e	34.80±0.052e	34.83±0.030e	34.87±0.030e	34.90±0.052e	34.83±0.039d
	T_2	31.70±0.052f	31.73±0.030f	31.70±0.052f	31.73±0.030f	31.80±0.052f	31.73±0.043e
	T_3	44.50±0.103b	52.57±0.079b	44.60±0.052b	44.63±0.060b	44.67±0.079b	44.59±0.080b
	T_4	52.53±0.108a	52.57±0.079a	52.60±0.090a	52.63±0.030a	52.70±0.052a	52.61±0.072a
pH	T_0	3.14±0.005bc	3.15±0.003ab	3.16±0.003ab	3.18±0.003a	3.18±0.003a	3.16±0.004a
	T_1	2.88±0.008j	2.90±0.003j	2.92±0.003ij	2.93±0.003ij	2.93±0.003i	2.90±0.008e
	T_2	3.08±0.005ef	3.09±0.003def	3.11±0.005cde	3.12±0.003cd	3.12±0.005bc	3.10±0.004b
	T_3	3.04±0.003g	3.06±0.003fg	3.08±0.003fg	3.09±0.005ef	3.09±0.003cde	3.06±0.004c
	T_4	2.97±0.005h	2.98±0.006h	2.97±0.005h	2.98±0.003h	2.98±0.003h	2.97±0.005d
Acidity	T_0	0.14±0.005d-h	0.13±0.011a-d	0.12±0.005f-i	0.11±0.005a	0.10±0.006ghi	0.12±0.006c
	T_1	0.17±0.008e-h	0.16±0.005c-f	0.15±0.003f-i	0.14±0.005ab	0.13±0.005hij	0.15±0.005b
	T_2	0.13±0.005ghi	0.12±0.005c-g	0.11±0.005hij	0.10±0.008abc	0.09±0.008ijk	0.11±0.006c
	T_3	0.21±0.005hij	0.20±0.003d-h	0.19±0.005h-k	0.18±0.008abc	0.17±0.005jk	0.19±0.005a
	T_4	0.12±0.005h-k	0.11±0.008f-i	0.09±0.008ijk	0.08±0.005b-e	0.07±0.005**k**	0.10±0.006d
Acidity/Brix	T_0	0.003±0.002c	0.003±0.001cd	0.002±0.001cd	0.002±0.001cd	0.002±0.001d	0.002±0.001c
	T_1	0.010±0.002e	0.004±0.001e	0.004±0.001e	0.004±0.001e	0.003±0.001e	0.005±0.001d
	T_2	0.004±0.001f	0.003±0.001f	0.003±0.002f	0.003±0.002f	0.002±0.001f	0.003±0.001c
	T_3	0.004±0.001bc	0.004±0.001b	0.004±0.001b	0.004±0.001b	0.003±0.001bc	0.004±0.001b
	T_4	0.002±0.001a	0.002±0.001a	0.001±0.002a	0.001±0.001a	0.001±0.002a	0.001±0.001a

ketchup is shown in Table 4. The highest mean value of sodium was found in T4 at 0 day which was 45.83±0.388 in tomato ketchup. The lowest value of sodium value was noticed in the treatment of T2 which is 3.90±0.052 at 60 days. The highest mean value of potassium was found in T4 at 0 day which was 55.40±0.186 in tomato ketchup. The lowest value of potassium was noticed in the treatment of T0 which is 37.80±0.314 at 60 days. The highest mean value of calcium was found in T3 at 60 days which was 77.50±0.186 in tomato ketchup. The lowest value of calcium was noticed in the treatment of T1, which is 0.87±0.030 at 60 days. The highest mean value of magnesium was found in T3 at 0 day which was 2.72±0.001 in tomato ketchup. The lowest value of magnesium was noticed in the treatment of T1 which is 0.55±0.013 at 60 days. The highest mean value of iron was s in T1 at 0 day which was 0.95±0.012 in tomato ketchup. The lowest value for iron was observed in the controlled treatment T0 0.73±0.006 at 60 days. The highest mean value of zinc was found in T1 at 0 day which was 0.59±0.003 in tomato ketchup. The lowest value for zinc was observed in the T2 0.35±0.001 at 60 days. During storage, in mineral content of ketchup minor increased or decreases occur due to the syneresis process or increase in moisture content otherwise as such no changes observed in the ketchup.

***Organoleptic evaluation of tomato ketchup*:** The organoleptic evaluation of tomato ketchup, particularly in comparing control samples with those containing hydrocolloids such as starch, carboxymethyl cellulose (CMC), pectin, and guar gum, reveals significant insights into how these additives influence the overall quality and consumer acceptance of the product during storage. The sensory attributes assessed typically include taste, texture, and overall acceptability, which are crucial for consumer preference. Hydrocolloids are known to modify the rheological properties of food products, which in turn affects their sensory characteristics.

Sensory scores for each parameter of the product are presented in Table 4. The highest mean value of color was found in T_0 at 0 day which was 7.67±0.298 in tomato ketchup. The lowest value of color was noticed in the treatment of T4 which is 1.00±0.001 at 60 days. The highest mean value of texture was found in T0 at 0 day which was 7.67±0.298 in

Table 4. Mineral profile of tomato ketchup.

	Treatments	Storage					Mean
		0 day	15th day	30th day	45th day	60th day	
Sodium	T_0	36.57±0.079d	36.33±0.030c	35.80±0.237d	36.30±0.137	36.10±0.052d	36.22±0.107c
	T_1	6.87±0.030e	6.73±0.030e	6.67±0.030e	6.40±0.052e	6.17±0.030e	6.57±0.034d
	T_2	4.17±0.079f	4.13±0.030f	4.17±0.060f	4.07±0.030f	3.90±0.052f	4.09±0.050e
	T_3	44.43±0.079ab	44.77±0.298ab	44.10±0.517b	42.43±0.298c	41.10±0.231c	43.37±0.381b
	T_4	45.83±0.388a	45.37±0.030c	45.20±0.052ab	45.33±0.166ab	45.23±0.418ab	45.39±0.211a
Potassium	T_0	38.8±0.052i	38.6±0.052i	38.30±0.052ij	38.20±0.052ij	37.80±0.314j	38.34±0.104e
	T_1	43.63±0.030d-g	43.47±0.079d-h	44.20±0.052d	44.13±0.030d	43.93±0.079de	43.87±0.054c
	T_2	43.33±0.166e-h	43.23±0.030e-h	43.10±0.052fgh	42.87±0.030gh	42.70±0.052h	43.05±0.066d
	T_3	45.53±0.149c	45.47±0.079c	43.70±0.274def	43.90±0.137de	43.80±0.314def	44.48±0.191b
	T_4	55.40±0.186a	55.30±0.052a	55.13±0.030a	49.83±0.030b	49.67±0.030b	53.07±0.066a
Calcium	T_0	17.6±0.137g	17.83±0.030g	17.67±0.108g	17.10±0.103g	16.23±0.079h	17.29±0.091c
	T_1	4.97±0.303j	0.83±0.030j	0.80±0.052jk	0.80±0.052jk	0.87±0.030k	0.82±0.043e
	T_2	8.17±0.030i	1.40±0.052i	1.27±0.079i	1.07±0.079i	1.03±0.060i	1.22±0.078d
	T_3	77.50±0.186a	77.47±0.079a	76.47±0.265b	75.50±0.186c	74.90±0.155c	76.37±0.174a
	T_4	20.50±0.052d	20.40±0.052de	20.23±0.060de	19.60±0.052ef	18.80±0.052f	19.91±0.053b
Magnesium	T_0	2.05±0.001c	2.03±0.007c	2.02±0.001c	2.03±0.007c	2.03±0.008c	2.03±0.005b
	T_1	0.57±0.002e	0.54±0.006e	0.56±0.008e	0.56±0.008e	0.55±0.013e	0.55±0.007d
	T_2	1.15±0.001d	1.15±0.003d	1.13±0.005d	1.14±0.006d	1.14±0.010d	1.14±0.005c
	T_3	2.72±0.001a	2.72±0.003a	2.68±0.019a	2.64±0.044a	2.42±0.136b	2.64±0.040a
	T_4	2.06±0.001c	2.04±0.009c	2.00±0.001c	2.03±0.015c	2.04±0.001c	2.04±0.005b
Iron	T_0	0.79±0.000ab	0.78±0.006b	0.73±0.003b	0.74±0.024b	0.73±0.006b	0.75±0.008c
	T_1	0.95±0.012a	0.95±0.013a	0.95±0.012a	0.95±0.012a	0.75±0.036b	0.91±0.017a
	T_2	0.86±0.000ab	0.80±0.041ab	0.84±0.060ab	0.86±0.001ab	0.74±0.022b	0.82±0.025b
	T_3	0.88±0.000b	0.86±0.002	0.76±0.024b	0.82±0.042ab	0.82±0.041ab	0.83±0.022b
	T_4	0.84±0.003ab	0.79±0.035ab	0.76±0.042b	0.76±0.044b	0.79±0.035ab	0.79±0.032bc
Zinc	T_0	0.42±0.000ab	0.41±0.003ab	0.38±0.035ab	0.39±0.020ab	0.38±0.019ab	0.40±0.015b
	T_1	0.59±0.003ab	0.52±0.048ab	0.49±0.049ab	0.47±0.061ab	0.45±0.060ab	0.50±0.044a
	T_2	0.35±0.001b	0.33±0.017b	0.37±0.021ab	0.45±0.063ab	0.35±0.001b	0.37±0.020b
	T_3	0.48±0.003ab	0.41±0.032ab	0.43±0.023ab	0.42±0.035ab	0.41±0.056ab	0.43±0.030ab
	T_4	0.30±0.003b	0.43±0.076ab	0.31±0.016b	0.41±0.078ab	0.41±0.032ab	0.37±0.041b

Table 5. Organoleptic properties of tomato ketchup.

Parameters	Treatments	Storage					Mean
		0 day	15th day	30th day	45th day	60th day	
Color	T_0	7.67±0.298a	6.67±0.298ab	5.67±0.298ab	4.67±0.298ab	2.33±0.298ab	5.40±0.298a
	T_1	7.33±0.298abc	6.00±0.001a-d	5.00±0.517b-e	3.67±0.597ab	2.33±0.298a-d	4.87±0.342ab
	T_2	7.00±0.001b-e	5.67±0.298c-f	5.00±0.001c-f	3.33±0.298b-e	1.67±0.298efg	4.53±0.197b
	T_3	7.00±0.001def	7.00±0.001fg	5.67±0.298fgh	4.00±0.001efg	2.67±0.597i	5.27±0.197a
	T_4	7.00±0.001ghi	6.00±0.001ghi	4.00±0.517hi	1.33±0.298ghi	1.00±0.001i	3.87±0.163c
Texture	T_0	7.67±0.298a	6.33±0.298abc	4.67±0.298ab	3.00±0.001abc	1.34±0.298ab	4.60±0.293a
	T_1	7.00±0.001a-d	5.67±0.298b-e	4.33±0.298b-e	3.00±0.001c-f	1.67±0.298b-e	4.33±0.179ab
	T_2	7.33±0.298d-h	5.67±0.298e-h	5.00±0.001d-g	4.00±0.517f-i	1.34±0.298d-g	4.67±0.282a
	T_3	7.00±0.517h-k	5.33±0.298h-k	3.67±0.298e-h	2.00±0.001ijk	1.33±0.298g-j	3.87±0.282b
	T_4	7.33±0.298k	5.67±0.298jk	5.00±0.001k	3.33±0.298k	1.67±0.298jk	4.60±0.293a
Taste	T_0	7.67±0.597a	5.67±0.298abc	3.67±0.298ab	2.67±0.298abc	1.33±0.298ab	4.20±0.358ab
	T_1	7.00±0.001b-e	5.67±0.298b-e	4.00±0.001a-d	2.67±0.298d-g	1.33±0.298c-f	4.13±0.179ab
	T_2	7.33±0.298f-j	6.00±0.001e-i	4.33±0.298d-h	2.33±0.298f-j	1.33±0.298g-j	4.27±0.239ab
	T_3	7.00±0.001h-k	5.00±0.001h-k	3.67±0.298ijk	2.00±0.517jk	1.00±0.001g-j	3.73±0.163b
	T_4	7.33±0.298k	5.33±0.298k	5.00±0.001k	3.33±0.298k	1.33±0.298k	4.47±0.239a
Smoothness	T_0	7.00±0.517a	7.67±0.298a	6.33±0.298a	7.00±0.517a	7.67±0.298a	7.13±0.386a
	T_1	6.67±0.298a	7.33±0.298a	7.00±0.517a	6.67±0.298a	7.33±0.298a	7.00±0.342a
	T_2	6.67±0.298a	7.67±0.298a	6.34±0.298a	6.67±0.298a	7.67±0.298a	7.00±0.298a
	T_3	7.33±0.298a	6.67±0.298a	7.00±0.517a	7.33±0.298a	7.33±0.298a	7.13±0.298a
	T_4	7.00±0.517a	7.33±0.298a	7.67±0.298a	7.33±0.298a	7.67±0.298a	7.40±0.342a
Spreadability	T_0	7.33±0.298a	7.67±0.298a	6.33±0.298a	7.00±0.517a	7.67±0.298a	7.20±0.428a
	T_1	6.67±0.298a	6.67±0.298a	6.33±0.298a	6.67±0.298a	6.67±0.298a	6.60±0.298a
	T_2	6.67±0.298a	7.33±0.298a	7.33±0.298a	6.67±0.298a	7.67±0.298a	7.00±0.298a
	T_3	6.67±0.298a	7.33±0.298a	7.33±0.298a	6.67±0.298a	6.67±0.298a	6.93±0.298a
	T_4	6.67±0.298a	6.67±0.298a	7.00±0.517a	6.67±0.298a	7.33±0.298a	6.87±0.342a
Overall	T_0	8.33±0.298a	7.33±0.298a-d	6.33±0.298abc	4.67±0.298abc	3.33±0.298ab	6.00±0.298ab
Acceptability	T_1	6.67±0.298abc	5.67±0.298b-f	5.67±0.298a-e	5.33±0.298a-e	5.33±0.298a-d	5.73±0.298ab
	T_2	7.33±0.298a-e	6.33±0.298b-f	5.33±0.298b-f	4.67±0.298c-g	3.67±0.298c-g	5.47±0.358b
	T_3	7.33±0.298d-g	6.33±0.298c-g	5.33±0.298d-g	4.33±0.298efg	4.33±0.597b-f	5.53±0.358ab
	T_4	7.67±0.298g	6.67±0.298c-g	5.33±0.298fg	5.67±0.298efg	5.33±0.298efg	6.13±0.298a

tomato ketchup. The lowest value of texture was noticed in the treatment of T3 which is 1.33±0.298 at 60 days. The highest mean value of taste was found in T0 at 0 day which was 7.67±0.597 in tomato ketchup. The lowest value of taste was noticed in the treatment of T3, which is 1.00±0.001 at 60 days. The highest mean value of smoothness was found in T4 at 30 day which was 8.00±0.001 in tomato ketchup. The lowest value of smoothness was noticed in the treatment of T4 which is 6.33±0.298 at 30 days. The highest mean value of spreadability was found in T0 at 15 day which was 8.00±0.002 in tomato ketchup. The lowest value of spreadability was noticed in the treatment of T2 which is 6.33±0.298 at 30 days The highest mean values of overall acceptability were found in T_0 at 0 day which was 8.33±0.298 in tomato ketchup. The lowest value for the overall acceptability was observed in the treatment of T_2 3.00±0.001 at 60 days.

***Rheological Properties of tomato ketchup*:** The rheological properties of tomato products are considered one of the most important quality attributes since they influence product processing parameters, especially flow properties during transport, as well as consumers' acceptability. Besides agronomic (variety, maturity, etc.) and processing (heat treatment, mashing, storage, etc.) parameters, the differences in rheological behavior are the consequence of specific tomato product structures (Torbica *et al.*, 2016).

***Texture (Hardness)*:** Statistical results regarding texture (hardness) indicated that the effects of treatment, storage, and combined effects of storage of tomato ketchup on texture (hardness) were observed to be highly significant (Table 5). The impact of treatments on the texture (hardness) of tomato ketchup indicated that the highest texture (hardness) was observed with the mean value of was observed for ketchup containing pectin 2% (1.27 N). In comparison, the minimum texture (hardness) was found for ketchup containing starch 2% (0.60 N). The interactive effect of treatments and storage times on the texture (hardness) of tomato ketchup indicated that significantly the highest value was observed in the T4 at storage times of 0 days with the mean value of 1.27 ± 0.079 N/mm^2 and the lowest value was observed in T0 at storage times of 45 days with the mean value of 0.6 ± 0.05 N. The results of this study show that the texture (hardness) of tomato ketchup decreases with storage time.

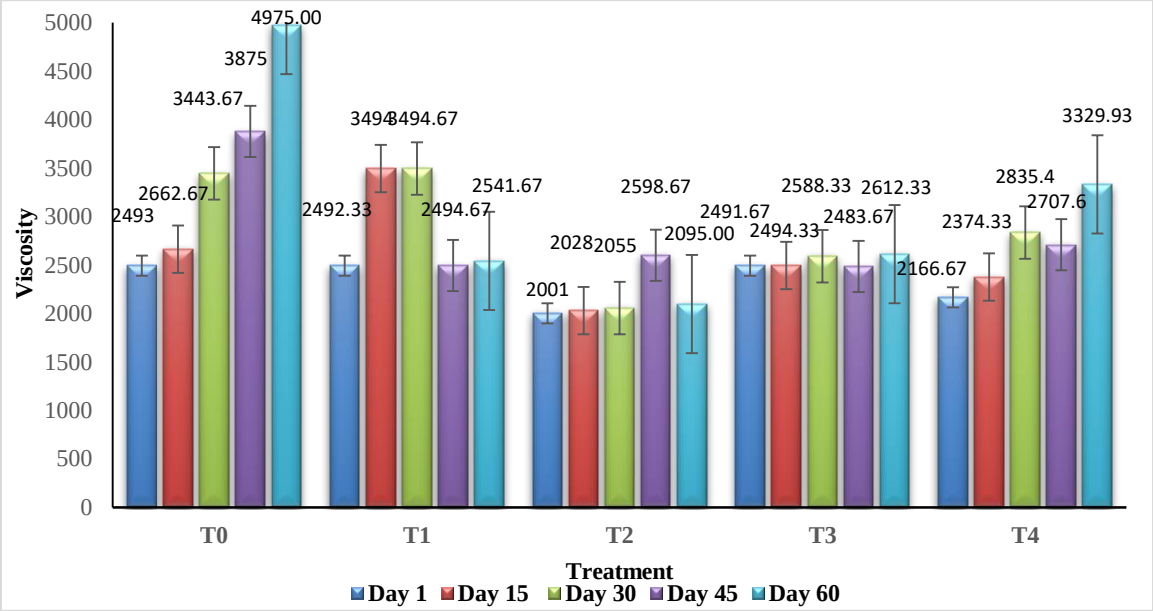

Figure 1. Combined effect of treatments and days on viscosity of tomato ketchup.

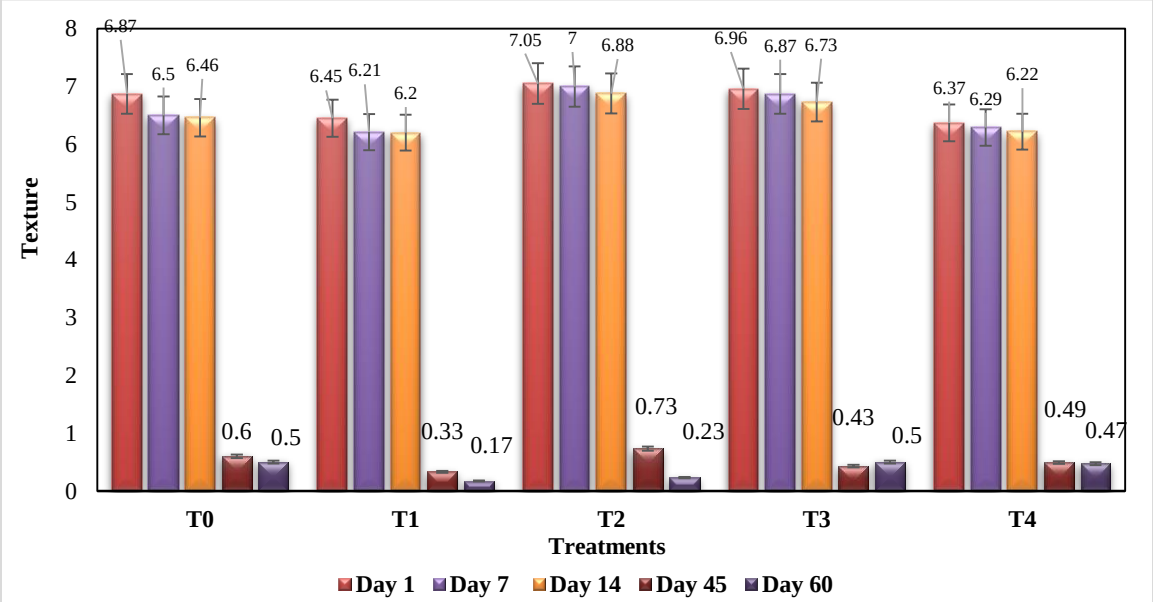

Figure 2. Combined effect of treatments and days on the hardness of tomato ketchup.

***Viscosity*:** The viscosity of the ketchup is an essential factor in its acceptance by the consumer; therefore, it is also considered in the commercial production of ketchup (Shokraneh *et al*., 2023).

As can be seen from Fig.2, the addition of each of the hydrocolloids (starch, guar gum, CMC, and pectin) separately significantly affected the viscosity of the samples produced.

The interactive effect of treatments and storage times on the viscosity of tomato ketchup indicated that significantly the highest value was observed in the T4 at storage times of 60 days with the mean value of 4425.67± 0.079 mPa.S and the lowest value was observed in T2 at storage times of 0 days with the mean value of 2001 ± 0.05 mPa.S.

DISCUSSION

In this investigation, the mean values for tomato ketchup's moisture, crude fat, crude protein, fiber, ash content and

carbohydrate were determined to be 72.96±0.246%, 0.47±0.030%, 3.14±0.075%, 0.99±0.107%, 1.17±0.218% and 22.24±0.202%, respectively. These outcomes are in line with the findings of Igwemeka and Eze (2023) discovered. The results also align with the findings of Kamil *et al.,* (2011). A study by Tapia *et al*. (2020) discusses how moisture levels in food products can influence microbial growth and spoilage, emphasizing the importance of moisture control in ketchup formulations. According to the findings of (Sharoba *et al.,* 2005) moisture content of different tomato ketchup ranges from 66.65% to 75.64 %. According to (Kamil *et al.,* 2011) moisture content of tomato ketchup is 71.43%.

By comparing these results with prior research, it can be seen that certain stabilizers affect the content of protein in food products. For example, guar gum has been shown to enhance the structural integrity of proteins, increasing the amount of protein in the finished product. However, pectin—which is mainly recognized for its ability to gel - may interact with the protein differently, leading to a decrease in the amount of protein. The obtained results of protein are also approximately equal to the values found by Igwemeka and Eze (2023).

From a technological perspective, the formulation of low-fat ketchup has been facilitated by the use of various thickening agents and hydrocolloids, which help maintain the desired texture and mouthfeel typically associated with traditional ketchup. Research has shown that ingredients such as konjac-mannan and xanthan gum can effectively replace fat while preserving the product's sensory qualities (Mirzaei *et al.,* 2018). These advancements allow manufacturers to create low-fat versions of ketchup that do not compromise on taste or texture, thereby appealing to health-conscious consumers without sacrificing product quality. The result of fat content was according to the findings of Igwemeka and Eze (2023).

The results of Sharoba et al. (2005) show that the ash level of tomato ketchup varies from 2.18% to 3.94%. Conversely, Kamil *et al.* (2011) observed a 1.1% ash content in tomato ketchup.

This study's results show that tomato ketchup's fiber content decreases with storage time. Gujral *et al.* (2002) also reported a similar trend.

According to Table 2, the control sample which had no additional hydrocolloids, had a higher mineral content because there were no interactions that could have influenced the analysis or the availability of the minerals. Similar trends were reported by Kamil *et al.,* (2011). On the other hand, the NFE content of the sample containing starch was lower, which could be attributed to the fact that starch is used for thickening without a corresponding increase in soluble carbohydrates. Similar trends were reported by Gujral *et al.* (2002).

The storage study revealed that the pH of tomato ketchup decreased over time. The findings of (Gamonpilas *et al.,* 2011) and (Sharoba *et al.,* 2005) are following the findings of the study. The acidity value of tomato ketchup decreases over time. The results are in collaboration with the results of Gamonpilas *et al.* (2011) and Sharoba *et al.* (2005). The TSS value of tomato ketchup increases with time. The results align with the findings of Gamonpilas *et al.* (2011) and Sharoba *et al.* (2005).

The outcomes of minerals were equivalent to (Din *et al.,* 2020). During storage, in mineral content of ketchup minor increases or decreases occur due to the syneresis process or increase in moisture content otherwise as such no changes are observed in the ketchup.

For instance, during prolonged storage, the control sample may experience changes in taste and texture due to ingredient degradation, while hydrocolloid-enriched samples tend to maintain their sensory attributes better (Kumar *et al*., 2015; Moqbali *et al*., 2020). This stability is crucial for ensuring that the product remains appealing to consumers throughout its shelf life. In conclusion, the sensory evaluation of tomato ketchup reveals that the incorporation of hydrocolloids such as starch, CMC, pectin, and guar gum significantly enhances the taste, texture, and overall acceptability of the product compared to control samples. These additives not only improve the rheological properties of ketchup but also contribute to a more enjoyable sensory experience, making them valuable ingredients in ketchup formulation, especially during storage.

The results of this study show that the texture (hardness) of tomato ketchup decreases with storage time. This similar trend was also reported by Mubarok and Ananda (2020).

As can be seen from Fig.2, the addition of each of the hydrocolloids (starch, guar gum, CMC, and pectin) separately significantly affected the viscosity of the samples produced. This similar trend was also reported by Mubarok and Ananda (2020). The apparent viscosity of the ketchup samples significantly increased with the addition of hydrocolloids in the formulations. The ability of the hydrocolloids to absorb water and the increase in the total solids of the samples as a result of the addition of the hydrocolloids can be considered the reasons for the increase in viscosity.

The result of my study shows that the appearance of tomato ketchup decreases with the storage time. The results of this study are similar to those (El-Desouky, 2016) and he also concluded that appearance decreases with storage time. The highest appearance value (8.00±0.517) was observed in T_0 at zero-day, while the lowest appearance value (1.33±0.298) was found in T_0 at the 60^{th} day of storage.

The findings of my study indicate that the color of tomato ketchup decreases over time during storage. This outcome is consistent with the study conducted by (Torbica *et al.,* 2016), which also reported a decrease in color with storage time. Among all treatments of ketchup, the highest color value was observed in T_0 at the beginning of the storage period with a mean value of (7.67±0.298). On the other hand, the lowest color value was found in T_4 at the 60^{th} day of storage with a mean of (1.00±0.000).

The result shows clear difference between the mean values of days and treatments in tomato ketchup's taste. The results align with the findings of (El-Desouky, 2016). The mean values for the treatment were recorded as 7.67±0.597, 7.00±0.000, 7.33±0.298, 7.00±0.000 and 7.33±0.298 for T_0, T_1, T_2, T_3 and T_4 respectively. The maximum mean value was founded in T_0 as 7.67±0.597 at 0 day. The minimum value was recorded as 1.00±0.000 for T_3 at 60th day.

The findings of the analysis of variance were significant ($p>0.05$) for zinc, sodium, potassium, lead and iron. The outcomes of minerals were equivalent to (Din *et al.*, 2020).

The texture was measured in tomato ketchup as with a mean value of 0.80±0.052, 0.60±0.225, 1.10±0.052, 1.20±0.052, 1.27±0.079 in T_0, T_1, T_2, T_3, T_4 respectively in this study. These findings match with those of Mubarok and Ananda (2020). Higher texture value was observed for ketchup containing pectin as a hydrocolloid and the lower texture value was observed for ketchup containing starch. During storage texture of ketchup is bad due to syneresis process which occur in ketchup. The viscosity of tomato ketchup was measured, with mean values of 2493.00±00.517, 2492.33±0.597, 2001±0.0.517, 2491.67±0.298, 2166.67±0.298 in T_0, T_1, T_2, T_3, T_4 respectively, in this study. These findings match with those of Mubarok and Ananda (2020).

Conclusion: In research, it was observed that tomato ketchup showed an increase in moisture content and a decrease in crude protein, crude fat, crude fiber, crude ash, and NFE. Additionally, the storage study indicated that the pH of tomato ketchup decreased over time. The acidity value of tomato ketchup decreases with time. A higher TSS value was observed for ketchup containing pectin and a lower TSS was observed for ketchup containing guar gum. The difference in results is due to the cultivation method, high sodium content present in the soil, and region of tomato production. During storage, in mineral content of ketchup minor increases or decreases occur due to the syneresis process or increase in moisture content otherwise as such no changes are observed in ketchup. The color, taste, and overall textural profile decreased as the storage time increased. Along with this, extended storage reduced the product's appearance, flavor, and general acceptability. Higher texture value was observed for ketchup containing pectin as a hydrocolloid and the lower texture value was observed for ketchup containing starch. During storage texture of ketchup is bad due to the syneresis process that occur in ketchup. Higher viscosity was observed for ketchup containing no hydrocolloid and the lower viscosity was observed for ketchup containing guar gum. During storage viscosity of ketchup increased with time.

***Author's contributions statement*:** Ramsha Akram, Aliza Batool and Khizar Hayat designed and completed the experiments; Hamna Saqib, Hunaina Saleem and Amna Sayal prepared the draft, Umar Farooq and Syed Muhammad Naqi Abbas reviewed, and finalized the draft.

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***Availability of data and material*:** We declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere.

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REFERENCES

Al-Dairi, M., P.B. Pathare and R. Al-Yahyai. 2021. Chemical and nutritional quality changes of tomato during postharvest transportation and storage. Journal of the Saudi Society of Agricultural Sciences 20:401-408.

Anlar, H.G. and M. Bacanli. 2020. Lycopene is an antioxidant in human health and diseases. In Pathology pp. 247-254.

AOAC. 2010. Association of Official Analytical Chemists. Official Methods of Analysis, 19th ed. Washington. D.C., U.S.A.

Baeghbali, S., S. Shahriari, S. and G. Pazuki. 2021. Effect of pressure homogenization and modified starch on the viscosity of ketchup: Experimental and modeling. Journal of Food Process Engineering 44:13683.

Bednar, J., A. Tauferova, B. Tremlova, J. Golian, R. Zidek and V. Vietoris. 2015. Determination of ketchup sensory texture acceptability and examination of determining factors as a basis for product optimization. International journal of food properties 18:660-669.

Cai, X., X. Du, G. Zhu, Z. Cai and C. Cao. 2020. The use of potato starch/xanthan gum combinations as a thickening agent in the formulation of tomato ketchup. CYTA-Journal of Food 18:401-408.

Cebolla-Cornejo, J., S. Roselló and F. Nuez. 2013. Phenotypic and genetic diversity of Spanish tomato landraces. Scientia Horticulturae 162:150-164.

Chukwuma, E. C. and M. O. Soladoye. 2012. Phytochemical analysis of the stem and root of *Cissus populnea* (Vitaceae)–an important medicinal plant in Central Nigeria. Phytologia balcanica 18:149-153.

Constantino, L. V., S. R. De Araujo, A. S. S. Fukuji, A.F. Nogueira, R.B. De Lima Filho, D.M. Zeffa, T.T. Nicio, C. Oliveira and L.S.A. Gonçalves. 2022. post-harvest characterization and sensory analysis of Roma tomato cultivars under organic cultivation: A strategy using consumers and chefs. International Journal of Gastronomy and Food Science 29:100564.

Din, A., R. M. Amir, K. Ameer, A. Ahmad, M. Nadeem, M.F.J. Chughtai and R. Kausar. 2020. Assessment of quality attributes of tomato sauce supplemented with moringa root. Food Science and Technology 40:1014-1020.

El-Desouky, L. 2016. Effect of hydrocolloids addition on rheological properties, and sensory quality of tomato ketchup during storage. Int. J. Food Prop. 5(1): 179-191.

Gamonpilas, C., W. Pongjaruvat, A. Fuongfuchat, P. Methacanon, N. Seetapan and N. Thamjedsada. 2011. Physicochemical and rheological characteristics of commercial chili sauces as thickened by modified starch or modified starch/xanthan mixture. Journal of food engineering 105:233-240.

Ghandi, A., A. Koocheki, S. A. Mortazavi, S. M. Razavi and T. Vasiljevic. 2008. The rheological properties of ketchup as a function of different hydrocolloids and temperature. International Journal of Food Science & Technology 44:569-602.

Gujral, H. S., A. Sharma and N. Singh. 2002. Effect of hydrocolloids, storage temperature, and duration on the consistency of tomato ketchup. International journal of food properties 5:179-191.

Igwemeka, C. J. and C. R. Eze. 2023. Proximate and nurtional composition of ketchup produced from two local tomato varieties (*Solanum lycopersicum*) stabilized with Okoho (*Cissus populnea*) gum extract.

Komeilyfard, A., M. Fazel, H. Akhavan and A. Mousakhani Ganjeh. 2017. Effect of Angum gum in combination with tragacanth gum on rheological and sensory properties of ketchup. Journal of Texture Studies 48:114-123.

Komeilyfard, A., M. Fazel, H. Akhavan and A. Mousakhani Ganjeh. 2017. Effect of Angum gum in combination with tragacanth gum on rheological and sensory properties of ketchup. Journal of texture studies 48:114-123.

Kumar, T., S. Chandra, S. Singh, N. Chauhan and J. Singh. 2015. Effect of different hydrocolloids on the quality of ketchup during storage. South Asian J. Food Technol. Environ 1:152-159.

Kamil, M. M., G. F. Mohamed and M. S. Shaheen. 2011. Fourier transformer infrared spectroscopy for quality assurance of tomato products. J. Am. Sci. 7:559-572.

Manzoor, M., J. Singh, J.D. Bandral, A. Gani and R. Shams. 2020. Food hydrocolloids: Functional, nutraceutical and novel applications for delivery of bioactive compounds. International Journal of Biological Macromolecules 165:554-567.

Mirzaei, M., M. Alimi, S. Shokoohi and L. Golchoobi. 2018. Synergistic interactions between konjac-mannan and xanthan/tragacanth gums in tomato ketchup: Physical, rheological, and textural properties. Journal of texture studies 49:586-594.

Montgomery, D.C. 2017. Design and analysis of experiments, Jhonwiley & sons. NY, USA.

Moqbali, F. H. A., M.A.A. Rabaaniand N.A.A. Ghaithi. 2020. Physico-Chemical Analysis of Various Samples of Tomato Ketchup. Asian Journal of Applied Chemistry Research 6:59-66.

Mubarok, A.Z. and F.Y. Ananda. 2020. Effect of concentration of porang flour and temperature on rheological properties of tomato ketchup. In *IOP* Conference Series: Earth and Environmental Science 475:12-34.

Sharoba, A. M., B. Senge, H. A. El-Mansy, H. E. Bahlol and R. Blochwitz, R. 2005. Chemical, sensory and rheological properties of some commercial German and Egyptian tomato ketchups. European Food Research and Technology 220:142-151.

Shokraneh, N., M. Alimi, S.A. Shahidi, M. Mizani, M. Bameni Moghadam and A. Rafe. 2023. Textural and rheological properties of sliceable ketchup Gels 9:222.

Sugino, N., T. Watanabe and H. Kitazawa. 2022. Effect of transportation temperature on tomato fruit quality: chilling injury and the relationship between mass loss and a* values. Journal of Food Measurement and Characterization 1-6.

Tapia, M. S., S.M. Alzamora and J. Chirife. 2020. Effects of water activity (aw) on microbial stability as a hurdle in food preservation. Water activity in foods: Fundamentals and applications 323-355.

Torbica, A., M. Belovic, J. Mastilovic, Z. Kevresan, M. Pestoric, D. Skrobot and T.D. Hadnađev. 2016. Nutritional, rheological, and sensory evaluation of tomato ketchup with increased content of natural fibers made from fresh tomato pomace. Food and Bioproducts Processing 98:299-309.

Wohner, B., V.H. Gabriel, B. Krenn, V. Krauter and M. Tacker. 2020. Environmental and economic assessment of food-packaging systems with a focus on food waste. Case study on tomato ketchup. Science of The Total Environment 738:139846.